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FINAL PROJECT REPORT

LIFE HISTORY AND ECOLOGY OF THE DESERT KIT FOX NEAR A SOLAR ENERGY PLANT

Upper Chuckwalla Valley, California

Prepared for: California Energy Commission
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PREFACE

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Life History and Ecology of the Desert Kit Fox Near a Solar Energy Plant, Upper Chuckwalla Valley, California is the final report for the Effect of Utility-Scale Solar Development and Operation on Desert Kit Foxes project (contract number PIR-11-012) conducted by Randel Wildlife Consulting, Inc. The information from this project contributes to Energy Research and Development Division's Energy-Related Environmental Research Program.

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ABSTRACT

Renewable energy has increased in California's desert regions in the past decade due to California's Renewable Portfolio Standard and the American Recovery and Reinvestment Act of 2009 funding. Limited information on the life history and ecology of desert kit foxes reduces the effectiveness of environmental impact assessments and developing suitable strategies to avoid or mitigate impacts. To address knowledge gaps, researchers fitted 56 desert kit foxes with mortality-sensitive radio collars in the Upper Chuckwalla Valley, California, near the Desert Sunlight Solar Farm. They used standard radio-telemetry techniques to locate individuals 5–7 nights per week and used these data to estimate home range, survival, and reproductive rates. Mean annual home ranges were larger than previously reported for kit foxes. Researchers found no difference between male and female study survival rates, which were similar to estimates from Utah and Lokern Natural Area, but higher than other studies. Predation accounted for 92 percent of all mortalities, with coyotes as the major predator. Infectious disease antibodies were detected in 27 percent of tested kit foxes with no disease related mortalities during the study. Canine distemper virus prevalence (19 percent) was highest during fall 2012, similar to prevalence rates at Camp Roberts, but higher than other studies. Half of the radio-collared female desert kit foxes reproduced in 2013 and 2014. The desert kit fox population had high genetic variation and no evidence of inbreeding or subdivision. Results from this study provide baseline life history data for desert kit foxes in the Colorado Desert, which may be used during the environmental assessment and environmental planning process. While impacts associated with habitat loss and increased anthropogenic activity may potentially affect kit foxes during construction, long-term impacts associated with operational activities are unknown.

Keywords: Desert kit fox, Disease, Genetics, Home Range, Survival, Reproduction, Riverside County, Utility-Scale Solar, *Vulpes macrotis arsipus*

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EXECUTIVE SUMMARY

Introduction

The United States has experienced substantial growth in renewable energy generation capacity in the past decade – California's electricity generated from renewable energy resources jumped from about 10 percent to almost 19 percent during that time. The state's Renewable Portfolio Standard - the nation's most aggressive renewable energy goal - requires a 33 percent contribution to the electrical grid from renewable energy by 2020. This combination of clean energy goals, a high solar energy generation potential, declining cost of solar energy development, and federal assistance from the American Recovery and Reinvestment Act of 2009, however, is increasing pressure to develop California's southeastern desert to help meet this renewable energy goal.

The growing reliance on California's desert ecosystems to produce renewable energy could have an unintended effect on species found in these areas. To better understand potential effects of large scale land conversion and development in the southeastern deserts it is imperative to have reliable scientific data to inform decision makers (e.g., regulatory agencies and policy makers) and project proponents (e.g., developers) and to support implementing the Desert Renewable Energy Conservation Plan.

Project Purpose

The desert kit fox (*Vulpes macrotis arsipus)* is one of the potentially impacted species from this development, and the direct and indirect impacts to them during construction and operations of utility-scale solar energy facilities are not well understood. To address these knowledge gaps, improve pre-construction impact assessments, and provide reliable data to interested parties; Randel Wildlife Consulting, Inc. conducted a two-year desert kit fox radio-telemetry study to collect baseline life history and ecological in the Upper Chuckwalla Valley, Riverside County, California, adjacent to the 550 megawatt Desert Sunlight Solar Farm. The study characterized life history traits (e.g., survival, mortality, reproduction, disease prevalence, and genetic diversity) and home range size and overlap of desert kit foxes within an area being developed for utility-scale solar energy generation.

Project Results

Randel Wildlife Consulting, Inc. captured 101 desert kit foxes between October 2012 and May 2014. Within this period, the researchers fitted 56 desert kit foxes with radio collars and relocated these foxes 5–7 nights per week using standard radio-telemetry techniques. They used location data to calculate seasonal and annual home range size and associated overlaps. They additionally used radio-telemetry, combined with live trapping, to estimate seasonal and annual survival rates and determine reproductive success and rate. Researchers additionally collected samples to test for disease antibodies and characterize population genetics during live trapping sessions. Annual home range size during the study was larger than previously reported for kit foxes. Home range overlap was higher for mated pairs (70.4–81.9 percent) when compared to other dyad groups (two individuals maintaining a significant relationship) (18.0–28.5 percent). Desert kit fox survival rates in the Upper Chuckwalla Valley during the study

were similar to estimates from Utah and Lokern Natural Area, California, and were higher than Kern County, Carrizo Plain National Monument, Camp Roberts, and the Naval Petroleum Reserves in California. Consistent with other studies, predation (hunted by other animals) was the primary cause of mortality, with coyotes the dominant kit fox predator. Half of the radio-collared female desert kit foxes reproduced during the 2013 and 2014 breeding season. Mean litter size (pups/female) was slightly higher in 2013 than 2014 and reproductive rates were lower than previously reported in other studies. About a quarter of desert kit foxes that were sampled for infectious diseases tested positive for at least one infectious disease antibody during the study. Canine distemper virus was detected in about one in five foxes during the study, which is similar to rates reported for Camp Roberts, and higher than rates reported in other areas of the kit foxes' range. Canine parvovirus was the second most prevalent disease (3–11 percent) during this study, which is lower than previously reported prevalence rates.

Project Benefits

This research provides scientifically collected baseline data on the ecology and life history traits of the desert kit fox found at a utility-scale solar energy development in California. Data collected supporting this project provides reliable estimates of home range size, reproductive success/rate, survival, causes of mortality, disease prevalence, and genetics, which can be used in the decision making process to assess potential impacts to desert kit foxes from utility-scale solar energy development. This information helps California move forward with proactive mitigation efforts to expedite permitting renewable energy projects and support the Desert Renewable Energy Conservation Plan.

CHAPTER 1:
Introduction

1.1 Utility-Scale Renewable Energy Development in California

Over the past decade, renewable energy generation capacity has increased substantially in the United States (Bird et al. 2005, Carlisle et al. 2014). In California, the percent of total electrical generation from renewable energy increased from 10.2% in 2004 to 18.77% in 2014[1]. During the same period solar energy production increased from 0.3% to 1.82% of the total electrical generation capacity. The increase in renewable energy contribution to the electrical grid is state mandated under California's Renewable Portfolio Standards (RPS; Senate Bill 1078). California's RPS is considered the most aggressive in the nation and requires a 33% contribution to the electrical grid from renewable energy sources by 2020 (Carley 2009). Aggressive RPS goals, federal incentives (e.g., grants and loans) under the American Recovery and Reinvestment Act of 2009 (Pub. L. 111-5), declining solar energy development costs (Carlisle et al. 2014), and high solar energy generation potential (Lopez et al. 2012) are placing increased development pressure on California's southeastern deserts.

Rural utility-scale solar photovoltaic (PV) has a projected nameplate capacity of 4,010 gigawatt (GW) in California with a generation estimate of 8,855,917 gigawatt-hours (GWh). Concentrated solar power has a projected 2,725 GW nameplate capacity with a 8,490,916 GWh generation estimate (Lopez et al. 2012). Current solar energy industry estimates on the land area required to install one megawatt (MW) of utility-scale solar ranges from 5–10 acres/MW and depends on facility type and siting location. The main advantage of solar energy systems are their reduced greenhouse gas emissions when compared to more traditional energy sources (Tsoutsos et al. 2005). Large-scale land use conversions of any type are likely to have both direct and indirect impacts to wildlife species residing within and adjacent to the proposed development. However, our understanding of solar development impacts on wildlife is limited, making assessments of appropriate minimization and mitigation for species inhabiting these areas difficult.

The State of California and the federal government initiated the Desert Renewable Energy Conservation Plan (DRECP) in 2009, covering more than 22 million acres in the California desert to identify preferred areas to develop about 20,000 MW of renewable energy and to conserve biological resources. The DRECP is an innovative, landscape-scale planning effort using a robust collection of the best available scientific information to develop a conservation plan that, once implemented, will be continuously monitored through 2040. At the time the DRECP was initiated, state and federal agencies determined more data was required about where animals and plants exist, how vulnerable they are to energy development, and what can be done to minimize those impacts.

[1] California Energy Almanac: http://energyalmanac.ca.gov/electricity/total_system_power.html, accessed 11 November 2014.

1.2 Desert Kit Fox

Kit foxes (*Vulpes macrotis*) are a small, nocturnally active, arid land fox species found in the southwestern United States and Northern Mexico (Figure 1; McGrew 1979). Throughout their range kit foxes are associated with desert and semi-arid regions in steppe or desert climates (McGrew 1979). There are five recognized kit fox subspecies (O'Neal et al. 1987), two of which occur in California: the state and federally endangered San Joaquin kit fox (*V. m. mutica*) and the California fully protected desert kit fox (*V. m. arsipus*). The two subspecies occupy separate and distinct ranges within the state with no population overlap. The desert kit fox subspecies is found in the Sonoran and Mojave Deserts of southern Nevada, Arizona, and California (McGrew 1979). In California, the desert kit fox has a 39,289 mi^2 potential range from southern Mono County south to the Mexican border; and from northwestern Los Angeles County east to the Arizona and Nevada borders (Figure 2).

Kit fox life history traits (e.g., reproduction, survival, mortality) and ecological parameters, such as home range (the area in which and animal normally travels and searches for food; Burt 1943) are highly variable both spatially and temporally. This variation in life history traits has been attributed to biotic (e.g., prey availability, predation, and competition) and abiotic (e.g., climate conditions and anthropogenic activity) conditions (Arjo et al. 2007, Warrick and Cypher 1998). For example, home range estimates range from 840 acres in Utah (O"Neal et al. 1987) to 3,509 ± 474 acres in western Arizona (Zoellick and Smith 1992), with home range overlaps varying based on pair bond status (e.g., paired or unpaired), population density, and prey availability (Zoellick and Smith 1992). Mated pairs exhibit the highest percentage of home range overlap (Zoellick and Smith 1992). Home range overlaps are non-exclusive use areas within an individual's home range. The degree of home range overlap within a population may be used to determine densities when all overlaps are known.

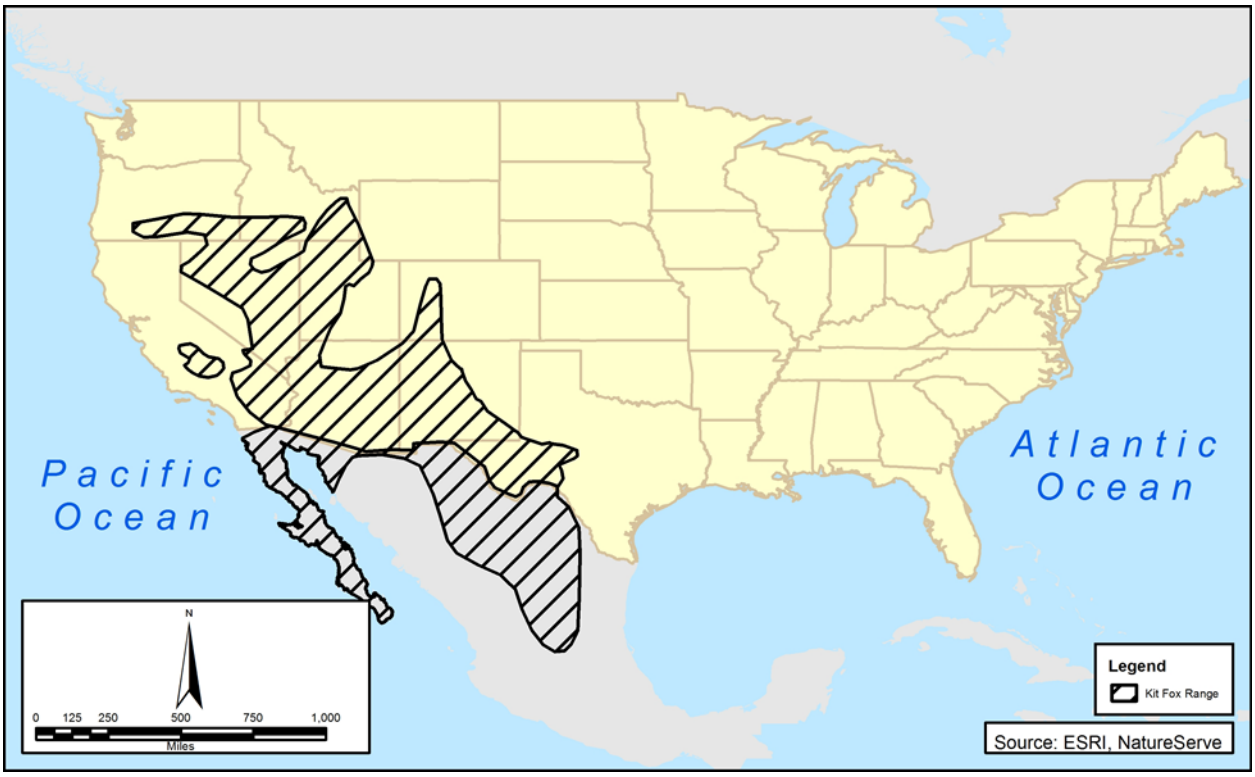
Kit foxes exhibit a socially monogamous mating system, which is characterized by long-term pair-bonds (Kleiman 1977) and individuals within the pair bonded maintaining distinct home ranges. The species is monestrous (Asa and Valdespino 2003), giving birth to a single litter of 1–7 pups annually (Ralls et al. 2007). Mating typically occurs in mid-winter (December to January) with pups whelped from mid-February to mid-March. Pups are nursed below ground for approximately 4 weeks, with both parents provisioning pups until they are fully independent at 5–6 months of age (Ralls et al. 2007). Males provision lactating females until pups are weaned with both parents provisioning pups until they are fully independent (Egoscue 1962).

As with home range size, survival rates and reproductive rates vary significantly, both spatially and temporally. Annual survival estimates range from 0.35 at the Naval Petroleum Reserves in California (Cypher and Scrivner 1992) to 0.84 at the Lokern Natural Area (Nelson et al. 2007). Predation is the most frequently cited kit fox mortality source with coyotes being the most common predator. Coyote predation of kit foxes is considered the strongest example of interspecific killing among North American carnivores (Palomares and Caro 1999). Vehicular strikes are also a significant mortality source for kit foxes in urban areas (Bjurlin et al. 2005), but rarely exceed 10 percent elsewhere and not considered significant enough to influence

population dynamics (Bjurlin and Cypher 2003). Infectious diseases, while present in kit fox populations, are not a significant mortality source (Cypher et al. 2000).

Additional information is required to more accurately evaluate and assess the potential impacts of utility-scale solar projects to desert kit fox populations at local and regional scales. When subject to stress, which can be caused by habitat alteration, kit foxes more easily succumb to disease. A recent outbreak of canine distemper among desert kit foxes caused concern and delay in solar project construction. Scientific research is needed to investigate disease prevalence and spread.

Figure 1: Range of the Kit Fox in North America



Source: ESRI, NatureServe

1.3 Objectives

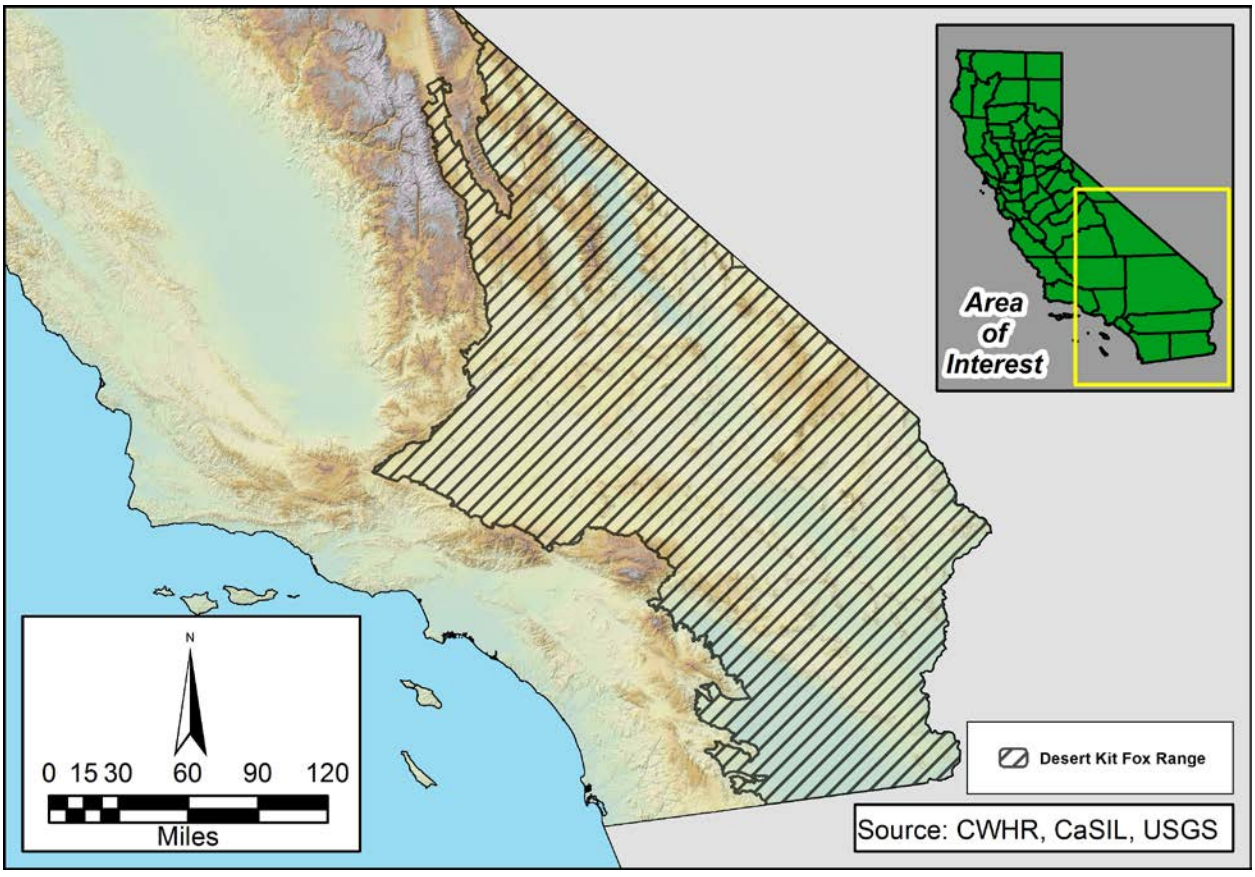
Research objectives were to characterize the following desert kit fox life history traits and baseline ecological parameters within an area being actively developed for utility-scale solar energy development:

- Annual and Seasonal Home Range Size and Percent Overlap
- Survival and Cause-Specific Mortality
- Reproductive Success (% females producing ≥ 1 pup) and Reproductive Rate (pups/female)

- Disease Prevalence (# of disease positive individuals/tested individuals)
- Genetic Relatedness among Individuals

This information can provide a scientific baseline for developing guidelines to evaluate utility-scale solar development impacts on the desert kit fox and inform the implementation of the DRECP.

Figure 2: Desert Kit Fox Range - California



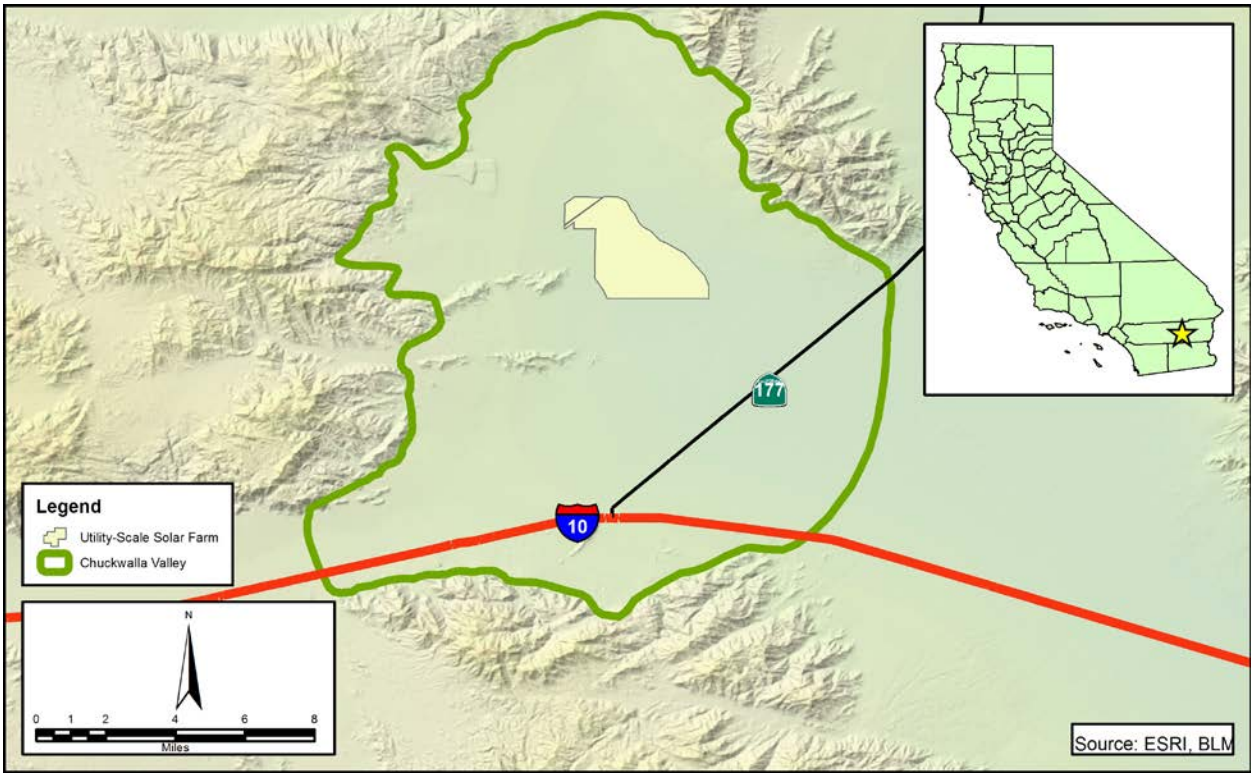
Source: California Wildlife Habitat Relationships, California Geoportal, USGS

1.4 Study Area

The study area (64,490 ac.) was located in the Upper Chuckwalla Valley, Riverside County, California near the community of Desert Center (33°43'N, 115°24'W; Figure 3). Elevation ranges from 650–1,150 ft. above mean sea level with topography sloping down from the northwest to southeast. The Upper Chuckwalla Valley is located in the Colorado Desert, a subregion of the Sonoran Desert (Steers and Allen 2011) and characterized by dry foresummers (April–June), summer precipitation (July–September; including summer monsoons), and variable fall and winter precipitation (October–March; Tubbs 1972, Adams and Comrie 1997, Higgins et al. 2004, Vera et al. 2006, Holmgren et al. 2010). Climate is typical of the Colorado Desert with a mean annual temperature of 74° F, December is the coldest month (41°–67° F) and July the hottest

month (82°–109° F). Mean annual precipitation is 3.1 in. Sonoran creosote bush scrub and dry desert wash woodland (Holland 1986) are the dominant vegetation types within the study area. The Bureau of Land Management manages 68% of our total study area, with 29% of lands under private ownership. Desert Sunlight Solar Farm, a 550-MW name plate capacity, utility-scale solar PV facility (≈3,700 ac.) was under construction in the north-central portion of the study area during this study (Figure 3).

Figure 3: Chuckwalla Valley, Riverside County, California



Source: ESRI, BLM

CHAPTER 2:
Home Range

Home range was first defined by Burt (1943) as an area traversed by an individual in its normal activities of food gathering, mating, and caring for young. Kit fox home range sizes vary widely based on geographic location, ranging from 741 ac. (O'Neal et al. 1987) to 3,509 ac. (Zoellick and Smith 1992). Researchers used nightly desert kit fox locations in an effort to address these questions: 1) What are the mean seasonal and annual desert kit fox home range sizes? 2) Do male and female mean seasonal and annual home range size differ? 3) What is the mean home range overlap for mated and unmated desert kit foxes? 4) How do mean seasonal home ranges, annual home range, and home range overlap in the Upper Chuckwalla Valley compare to other geographic areas? Using the mean annual home range size and percent overlaps may be used to derive estimated desert kit fox densities and estimate potential impacts associated with proposed developments.

2.1 Methods

2.1.1 Capture, Handling and Marking

Randel Wildlife Consulting, Inc. used wire-mesh live traps (Tomahawk Live Trap, Hazelhurst, WI) baited with meat scraps to capture desert kit foxes. All live trapping activities occurred outside of the breeding and whelping seasons (January–April) in accordance with California Department of Fish and Wildlife requirements. Live traps were set from approximately 1/2 hour before sunset with all traps checked and animals processed within 2 hours of sunrise the following morning. The researchers coaxed captured desert kit foxes from live traps into a canvas bag (Cypher et al. 2009) and weighed captured animals in the canvas bag. Once an individual's mass was calculated, the animal was secured by hand and a muzzle with an eye covering was placed to reduce stress and facilitate further processing. Researchers sexed, aged, and permanently marked each kit fox by ear tagging (unique field identification) and implanting a Passive Integrated Transponder (PIT) tag (unique permanent identification). A portion of the captured desert kit foxes were fitted with mortality-sensitive VHF radio collars (V5C 162C, Sirtrack, Havelock North, New Zealand) for radio-tracking (Figure 4). All individual desert kit foxes were released after processing and observed for signs of stress. All capture, handling, and marking activities were conducted in accordance with the American Society of Mammalogists Guidelines for the Use of Wild Animals in Research (Sikes et al. 2011) and authorized by a Memorandum of Understanding between Randel Wildlife Consulting, Inc. and the California Department of Fish and Wildlife.

2.1.2 Radio-Telemetry

Researchers tracked radio-collared desert kit foxes nightly using a vehicle with standard radio-telemetry techniques. This included triangulation, homing, and visual locations (Millspaugh et al. 2012). A Location Of A Signal (LOAS version 4.0.2, Heymagas, Hungary) software was used to estimate maximum likelihood locations for nightly triangulation data. Maximum likelihood locations (triangulation), homing locations, and visual locations were plotted in ArcGIS 10.1

(ESRI, Redlands, California, USA) and these data were exported for further analysis in the Geospatial Modelling Environment (GME; Beyer 2012).

2.1.3 Home Range and Home Range Overlap Calculation and Analysis

Randel Wildlife Consulting, Inc. calculated annual and seasonal 95% and 50% fixed kernel home ranges using the 'kde' feature in GME (Beyer 2012) for all individuals with ≥30 locations within each sampling period of interest. Researchers similarly used the 'genmcp' feature to calculate 100% minimum convex polygon (MCP) annual and seasonal [dispersal (Aug.–Oct.); pair formation (Nov.–Feb.); pup-rearing (Mar.–Jul.)] home range estimates in GME (Beyer 2012) for all individuals with ≥30 locations in the period of interest. Previous studies either used fixed kernel or MCP kit fox home ranges. This study calculated both fixed kernel and MCP home range estimates to facilitate comparison of results with these previous studies. A Mann-Whitney U test was used to compare seasonal and annual home range sizes between male and female desert kit foxes.

Figure 4: Desert Kit Fox with Mortality-Sensitive Collar

Photo Credit: Randel Wildlife Consulting, Inc.

Researchers calculated kernel annual and seasonal fixed kernel home and core range overlaps using the 'isectpolypoly' feature in GME (Beyer 2012) based on four dyad pairings: male-male (MM), female-female (FF), male-female unpaired (MF_U), and male-female paired (MF_P). The percent overlaps for each individual within the dyad were averaged to obtain the percent overlap for annual and seasonal home and core ranges. Researchers then used an Analysis of Variance (ANOVA) to test for differences in percent overlap between dyad groups. They determined percent home range overlaps for dyads to estimate the area of non-exclusive use for

mated and unmated neighboring individuals. Based on previous research we would hypothesize that mated pairs had a higher percentage of overlap than non-mated pairs.

2.2 Results

2.2.1 Capture, Handling and Marking

Researchers captured 101 desert kit foxes between October 2012 and May 2014. Forty desert kit foxes were fitted with mortality-sensitive radio collars from our initial sampling period (October 2012 to December 2012). An additional 16 desert kit foxes were fitted with mortality-sensitive radio collars to replace malfunctioning collars or those lost due to predation from May 2013 to December 2013. There was no capture-induced mortality during the study, with all animals surviving >14 days post capture.

2.2.2 Home Range and Home Range Overlap

2.2.2.1 Fixed Kernel Home Range

Randel Wildlife Consulting, Inc. found no statistically significant difference between male and female annual kernel home range ($P = 0.682$) or core range ($P = 0.381$) in 2012–2013. Researchers did not detect a statistically significant difference between male and female 10-month home range ($P = 0.894$) or core range ($P = 1.000$) for 2013–2014. The 10-month home range estimate is the home range area for the final 10 months of the study. There was no statistically significant difference in pair formation home range between male and female desert kit foxes in 2012–2013 ($P = 0.593$) or in 2013–2014 ($P = 0.704$). Randel Wildlife Consulting, Inc. similarly found no statistically significant difference between male and female pair formation core range in 2012–2013 ($P = 0.343$) or in 2013–2014 ($P = 0.842$). Additionally the researchers did not detect a statistically significant difference between male and female pup-rearing home range in 2013 ($P = 0.577$) or in 2014 ($P = 0.381$). Randel Wildlife Consulting, Inc. found no statistically significant difference between male and female pup-rearing core range in 2013 ($P = 0.760$) or in 2014 ($P = 0.713$). There was also no statistically significant difference between male and female dispersal home ($P = 0.341$) or core range ($P = 0.683$) (Table 1 and Table 2).

Table 1: 50% and 95% annual fixed kernel areas (± SE; acres) for male (M) and female (F) desert kit foxes, Upper Chuckwalla Valley (2012-2013).

	2012-2013														
	50%							95%							
	M				F			M				F			
Pair Formation	902	±	148		694	±	77		3855	±	603		3254	±	336
Pup-Rearing	892	±	114		813	±	104		3274	±	393		3744	±	499
Dispersal	806	±	101		853	±	72		3252	±	373		3998	±	390
Annual	904	±	99		940	±	96		3931	±	376		3862	±	356

Male and female kernel home and core range estimates were pooled based on year for the pair formation and pup-rearing seasons and compared between years. Home range size during pair formation season was greater in 2013 than 2014 ($P = 0.032$) with no statistically significant difference in core range size between 2013 and 2014 ($P = 0.094$). No statistically significant difference was found between pup-rearing home range size between 2013 and 2014 ($P = 0.081$) or core range between 2013 and 2014 ($P = 0.447$) (Table 1 and Table 2).

Table 2: 50% and 95% 10-month fixed kernel areas ($\bar{X}$ ± SE; acres) for male (M) and female (F) desert kit foxes, Upper Chuckwalla Valley (2013-2014).

	2013-2014														
	50%							95%							
	M				F			M				F			
Pair Formation	576	±	57		662	±	126		2785	±	336		2768	±	497
Pup-Rearing	714	±	126		998	±	366		2723	±	586		2693	±	235
Dispersal		-				-				-				-	
Annual	677	±	121		615	±	69		3338	±	756		2740	±	282

Mean annual home range was 3,897 ± 255 acres (range 1,396–6,909 acres) with a mean core range of 872 ± 69 acres (range 319–1,722 acres) for 2012–2013. The mean 10-month home range was 3,002 ± 363 acres (range 858–12,620 acres) with a mean core range of 643 ± 67 acres (range 121–2,088 acres). Mean core range size during pair formation was 709 ± 54 acres (range 67–2,483 acres). Mean home range during pup-rearing was 3,146 ± 222 acres (range 339–8,453 acres) with a mean core range of 833 ± 101 acres (range 96–6,027 acres).

2.2.2.2 Minimum Convex Polygon Home Range

Randel Wildlife Consulting, Inc. found no statistically significant difference between male and female annual MCP home range in 2012–2013 ($P = 0.820$), or between male and female 10-month MCP home range in 2013–2014 ($P = 0.788$). No statistically significant difference was found between male and female MCP pair formation home range in 2012–2013 ($P = 0.855$) or in 2013–2014 ($P = 0.910$). Researchers did not detect a statistically significant difference between male and female MCP pup-rearing home range in 2013 ($P = 0.059$) or in 2014 ($P = 0.966$) and additionally found no statistically significant difference between male and female MCP dispersal home range in 2013 ($P = 0.179$) (Table 3 and Table 4).

Table 3: Annual 100% MCP areas ($\bar{X}$ ± SE; acres) for male and female desert kit foxes, Upper Chuckwalla Valley (2012-2013 and 2013-2014).

	2012-2013				2013-2014[a]		
Male	4161	±	450		3941	±	1238
Female	4952	±	739		3178	±	358
Combined	**4567**	±	**437**		**3450**	±	**487**

[a] 10-month estimate

Male and female MCP home range estimates were pooled based on year for the pair formation and pup-rearing seasons to compare between years. Researchers found no significant difference between pooled MCP pair formation home range between 2012-2013 and 2013-2014 ($P = 0.111$). Similarly, they found no statistically significant difference in pooled MCP pup-rearing home range size between 2013 and 2014 ($P = 0.205$) (Table 3 and Table 4).

Table 4: Seasonal 100% MCP areas ($\bar{X}$ ± SE; acres) for male and female desert kit foxes, Upper Chuckwalla Valley (2012-2013 and 2013-2014).

	Pair Formation			Pup-Rearing			Dispersal
	2012-2013	**2013-2014**		**2012-2013**	**2013-2014**		**2012-2013**
Male	2486±388	2184±425		2362±297	2402±455		1,619±237
Female	2708±452	1858±247		3877±697	2424±260		2787±549
Combined	**2600±297**	**2014±237**		**3143±405**	**2414±250**		**2298±346**

The pooled annual MCP home range was 4,567 ± 437 acres (range 272–15,610 acres) for 2012-2013 with a mean pooled 10-month MCP home range of 3,450 ± 487 acres (range 598–15,660 acres) for 2013-2014. The pooled mean MCP home range during pair formation was 2,296 ± 190 acres (range 57–9,654 acres) and during pup-rearing was 2,763 ± 949 acres (range 27–10,800 acres). Mean combined MCP home range during dispersal was 2,298 ± 346 acres (range 361–10,550 acres).

2.2.2.3 Home Range Overlap

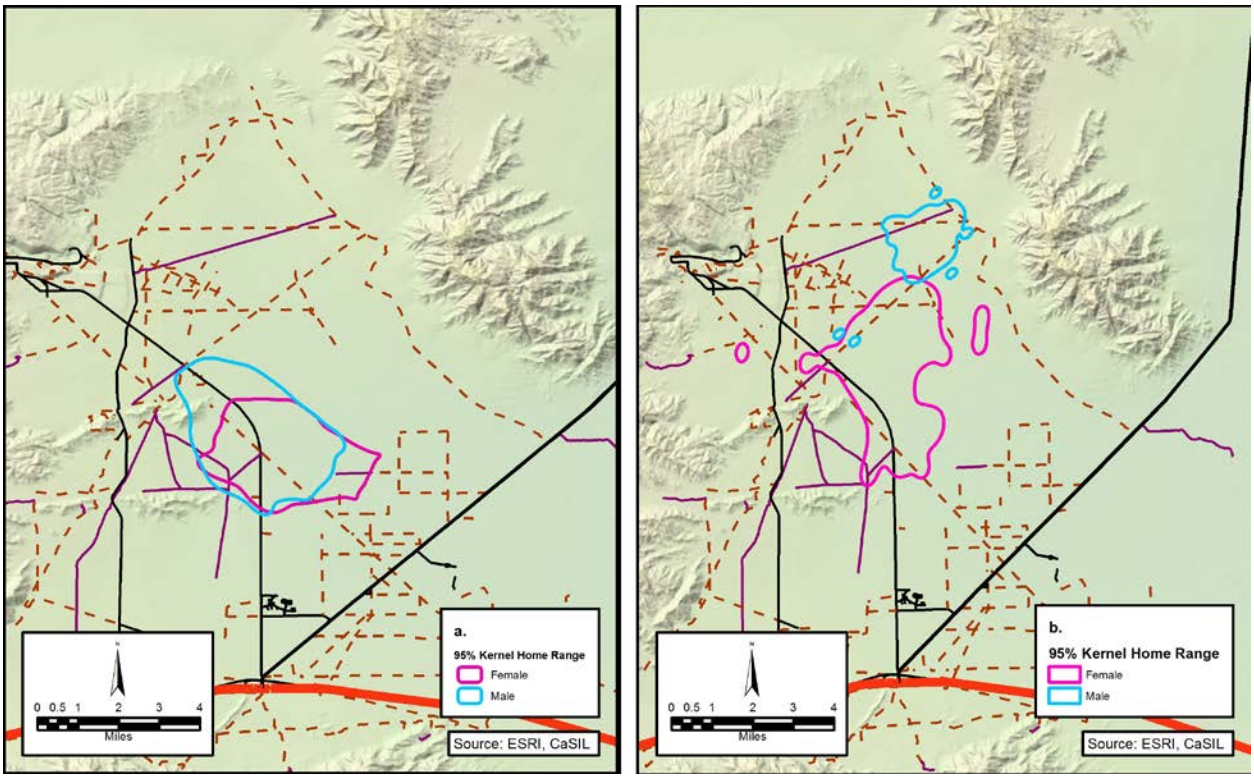
The data showed there was a statistically significant difference in 95% fixed kernel overlap for annual ($F_{3,152} = 31.32$, $P = 0.000$), pair formation ($F_{3,162} = 24.88$, $P = 0.000$), pup-rearing ($F_{3,138} = 30.54$, $P = 0.000$), and dispersal ($F_{3,89} = 17.64$, $P = 0.000$) in 2012-2013 (Table 5). Researchers similarly detected a statistically significant difference in 50% fixed kernel overlap for annual ($F_{3,57} = 28.98$, $P = 0.000$), pair formation ($F_{3,40} = 28.49$, $P = 0.000$), pup-rearing ($F_{3,34} = 20.49$, $P = 0.000$), and dispersal ($F_{3,29} = 19.08$, $P = 0.000$) in 2012-2013 (Table 5). A Tukey's post hoc test was conducted for each category and found no difference in percent overlap between the MM, FF, and MF_U dyads. In all post hoc analyses the MF_P dyad had significantly higher overlap than the remaining dyads (see example in Figure 5).

A statistically significant difference was found in 95% fixed kernel overlap for the 10-month ($F_{3,152} = 19.64$, $P = 0.000$), pair formation ($F_{3,156} = 20.76$, $P = 0.000$), and pup-rearing in 2013-2014 ($F_{3,86} = 17.37$, $P = 0.000$) (Table 6). Researchers similarly detected a statistically significant difference in 50% fixed kernel overlap for 10-month ($F_{3,43} = 7.75$, $P = 0.000$), pair formation ($F_{3,44} = 12.72$, $P = 0.000$), and pup-rearing ($F_{3,25} = 7.82$, $P = 0.000$) in 2013-2014 (Table 6). They additionally conducted a Tukey's post hoc test for each category and found no difference in percent overlap between the MM, FF, and MF_U dyads. In all post hoc analyses the MF_P dyad had significantly higher overlap than the remaining dyads.

Table 5: Annual and seasonal home (95%) and core (50%) range percent overlap ($\bar{X}$ ± SE) of female-female (FF), male-male (MM), male-female unpaired (MF_U), and male-female paired (MF_P) dyads, Upper Chuckwalla Valley (2012-2013).

Annual	FF			MM			MF_U			MF_P		
95%	19.9	±	2.4	19.9	±	2.4	21.5	±	1.8	77.6	±	1.8
50%	15.7	±	4.3	22.7	±	7.7	16.9	±	3.5	73.0	±	3.2
Pair Formation												
95%	19.1	±	2.3	20.5	±	2.6	24.6	±	2.1	70.4	±	1.6
50%	14.6	±	4.2	13.8	±	7.9	14.4	±	3.3	63.2	±	3.0
Pup-Rearing												
95%	21.6	±	2.9	18.0	±	3.1	21.9	±	2.4	79.7	±	2.6
50%	21.4	±	4.9	7.3	±	2.3	24.4	±	6.4	64.7	±	4.6
Dispersal												
95%	28.5	±	3.8	18.6	±	3.8	23.7	±	2.6	74.6	±	2.1
50%	18.0	±	3.7	20.2	±	19.9	14.4	±	3.3	60.4	±	4.4

Figure 5: Home Range Overlap of Paired (a) and Unpaired (b) Male and Female Desert Kit Foxes.



Source: Basemap from ESRI, California Geoportal

Table 6: 10-month and seasonal home (95%) and core (50%) range percent overlap ($\bar{X}$ ± SE) of female-female (FF), male-male (MM), male-female unpaired (MF_U), and male-female paired (MF_P) dyads, Upper Chuckwalla Valley (2013-2014).

10-Month	**FF**			**MM**			**MF_U**			**MF_P**		
95%	22.8	±	2.8[a]	21.3	±	4.1[a]	20.4	±	2.5[a]	81.9	±	1.7[a]
50%	25.7	±	8.7[a]	22.7	±	7.2[a]	19.9	±	5.7[a]	73.0	±	4.2[a]
Pair Formation												
95%	23.8	±	3.1	20.2	±	3.5	20.3	±	2.3	80.7	±	2.1
50%	32.1	±	7.4	20.1	±	7.3	19.2	±	4.7	73.8	±	0.8
Pup-Rearing												
95%	21.8	±	3.1	20.6	±	5.0	24.4	±	3.4	76.7	±	1.9
50%	18.9	±	10.2	14.8	±	7.8	18.6	±	8.0	66.1	±	4.4

[a] Partial year (no dispersal estimate)

2.3 Discussion

Annual home range sizes during our study, both MCP and fixed kernel, were larger than previously reported for kit foxes. Desert kit fox home range size (MCP) in western Arizona was

3,509 ± 474 acres (Zoellick and Smith 1992), which is 23% smaller than our estimate of 4,567 ± 437 acres. Differences between our study results and Zoellick and Smith (1992) may be attributed to Zoellick and Smith's (1992) small sample size (n = 7) and animal location frequency (6 hours per night, one night per month). By comparison, Randel Wildlife Consulting, Inc. located radio collared desert kit foxes 5–7 nights per week for the duration of our study, allowing us to obtain a greater number of locations, including long distance movements during the breeding season.

Researchers similarly compared our MCP annual home range estimates to studies of the San Joaquin kit fox (White and Ralls 1993, Cypher et al. 2001) and Mexican kit fox (List and Macdonald 2003). San Joaquin kit fox MCP home range estimates for the Carrizo Plains National Monument were 2,866 ± 222 acres, 37% smaller than our study. Cypher et al. (2001) reported an annual MCP home range size for San Joaquin kit foxes of 1,072 ± 331 acres for the Naval Petroleum Reserves in California, which is 77% smaller than our MCP home range estimate. List and Macdonald (2003) reported MCP home range estimates for Mexican kit foxes of 2,718 ± 1,137 acres, which is similar to annual MCP home range sizes reported by White and Ralls (1993), and 40% smaller than desert kit fox annual MCP home range size in the Upper Chuckwalla Valley.

Annual fixed kernel home range size during our study was 3,897 ± 376 acres. The fixed kernel home range estimate was smaller than our MCP home range estimate, likely due to the influence of outlier locations in MCP estimations. Fixed kernel home range estimates from our study were larger than previous studies reporting fixed kernel home ranges. List and Macdonald (2003) reported a fixed kernel home range size of 2,842 ± 1,013 acres for Mexican kit foxes, which is 27% smaller than our study estimate. San Joaquin kit fox fixed kernel home range size at the Lokern Natural Area was 1,460 ± 109 acres (Nelson et al. 2007) and was 37% smaller than home range estimates for desert kit foxes during our study.

All previously reported kit fox home range sizes regardless of the estimator (e.g., MCP or fixed kernel) were more consistent with the 10-month home range estimate than the annual home range estimates. List and Macdonald (2003) cautioned comparing results between home range studies due to the influence of the estimator of choice (e.g., kernel or MCP). To facilitate comparison and more accurately represent this study results, both 100% MCP and 95% fixed kernel annual home ranges, as well as 50% fixed kernel (core range) were calculated. Larger home range estimates during our study could be related to multiple factors including: differences in vegetation community, prey availability, study objectives and methods, and sample size.

Annual home ranges during our study overlapped 77.6 ± 1.8% for mated pairs in 2012-2013, which is similar to mated pair home range overlaps reported for western Arizona (75 ± 6.1%; Zoellick and Smith 1992) and Utah (74.2%; Daneke et al. 1984). Annual home range overlaps for unpaired animals was 21.5 ± 1.8% in 2012-2013 and approximately two times higher than western Arizona (12 ± 2.6%; Zoellick and Smith 1992). Annual home range overlaps for adjacent males and females was 19.9 ± 2.4% in 2012-2013. Adjacent male home range overlap (20 ± 4.5%) but not with adjacent female home range (0%) reported for western Arizona (Zoellick and Smith

1992). Zoellick and Smith (1992) reported adjacent male pair formation was 22%, which is consistent with our findings during 2012-2013 (20.5 ± 2.6%) and 2013-2014 (20.2 ± 3.5%). Results from western Arizona during the pup-rearing season showed adjacent males had a home range overlap of 6% (Zoellick and Smith 1992), which is significantly less than the findings for 2013 (18.0 ± 3.1%) and 2014 (20.6 ± 5.0%). Morrell (1972), Zoellick et al. (1987), and O'Neal et al. (1987) reported highly overlapping home ranges but did not provide percentages with which these results could be compared.

Habitat productivity, prey availability, and population densities influence kit fox home range size (Zoellick and Smith 1992, Warrick and Cypher 1998). Arjo et al. (2007) reported kit fox densities were inversely correlated with coyote densities in Utah. Anecdotal evidence (e.g., chorus howling and remote cameras) indicated the presence of up to six coyote packs within our study area and could potentially explain larger desert kit fox home range sizes due to predator avoidance and interspecific competition for prey.

During this investigation, 19 desert kit foxes (8 males and 11 females) were located ≥1 time within the 3,700 acre, 550-MW utility-scale solar energy development during our study. A female helper fox, whelped within the solar site, was located 121 times (56% of all fixes) within the facility during our study. Most desert kit foxes with home ranges adjacent to the utility-scale solar energy site did not appear to actively avoid the facility or adjacent areas during nightly activities. Conversion of 3,700 acres of native habitat to energy development likely had an indirect impact to multiple desert kit foxes by directly affecting foraging opportunities.

CHAPTER 3:
Reproduction, Survival and Predation

Reproductive parameters (e.g., reproductive success, litter size, and reproductive rate) and survival/mortality rates are basic life history traits. These parameters are commonly used in wildlife studies to assess how populations are structured and change over time. Researchers used multiple data collection methods to address the following questions: 1) What is the reproductive success of female desert kit foxes? 2) What is the mean litter size? 3) What is the desert kit fox reproductive rate? 4) Do reproductive success, mean litter size, and/or reproductive rate vary by year? 5) What is the seasonal and annual survival rate? 5) Do male and female survival rates differ? 6) What is the primary cause-specific mortality source of desert kit foxes? Baseline reproductive and survival estimates may be used to assess potential long-term impacts resulting from operational utility-scale solar energy development. Using these data should account for natural variation in these parameters and associated environmental variation.

3.1 Methods

3.1.1 Reproductive Status and Rate

The researchers used radio-telemetry homing techniques (Millspaugh et al. 2012) to locate potential natal den complexes of radio-transmittered female desert kit foxes from late January to February, 2013 and 2014. They recorded potential natal den complex locations using a handheld Global Positioning System (GPS) unit (UTM NAD 83) and labeled each location with the animal's unique ID. Each natal den complex was monitored using both direct and indirect (e.g., remote camera), beginning in March, coinciding with suspected whelping. Direct and indirect observation methods were used to determine pup presence and date of emergence. Researchers considered female desert kit foxes reproductively successful if a single pup emerged from the natal den and calculated reproductive success rates as the number of successfully reproducing females divided by the number of radio-collared females during the pup-rearing period. They similarly calculated desert kit fox reproductive rates as the product of reproductive success and mean litter size.

3.1.2 Survival Estimation and Analysis

Randel Wildlife Consulting, Inc. calculated seasonal and annual desert kit fox survival rates in R (R Core Team 2013), using the staggered entry Kaplan-Meier estimator allowing for censoring due to radio failure, emigration, and multiple study entry periods (Pollock et al. 1989). Three seasonal survival periods—dispersal (August-October), pair formation (November-February), and pup-rearing (March-July)—were based on previous studies (Olson and Lindzey 2002, Kitchen et al. 2002, Zoellick et al. 1989) and modified based on study observations. A log-rank test ($\alpha = 0.05$) was used to compare male and female desert kit fox annual, seasonal, and study survival rates. They additionally used the log-rank test to compare seasonal survival rates between years based on sex.

3.1.3 Mortality Determination

Randel Wildlife Consulting, Inc. determined cause-specific mortality using a method similar to one described by Disney and Spiegel (1992). Each mortality site was examined for predator specific sign including tracks, scat, and hair as well as carcass disposition (e.g., buried or not buried). Carcasses were examined for puncture wounds and distance between puncture wounds were measured, if present (Ralls and White 1995).

3.2 Results

3.2.1 Reproductive Status and Rate

Half of radio collared desert kit fox females successfully reproduced in 2013 (8 of 16) and 2014 (8 of 16). Mean minimum number of pups observed per litter was 2.69 ± 0.30 (range 1–6) for the entire study period with 2.75 ± 0.25 (range 2–4) in 2013 and 2.63 ± 0.56 (range 1–6) in 2014. Mode litter size was three for both 2013 and 2014. Ten of 14 (71%) females successfully reproducing in 2013 survived to the 2014 breeding season with five of the 10 (50%) successfully reproducing in 2014. The reproductive rate was 1.38 in 2013, 1.32 in 2014, and 1.35 for our entire study.

3.2.2 Survival

The combined annual survival rate (2012-2013) during this study was 0.809. No statistically significant difference was found between male (0.752) and female (0.885) annual survival rates (χ_1^2 = 0.03, P = 0.862). Researchers similarly found no statistically significant difference between male (0.892) and female (0.772) 11-month survival rates (survival estimate for final 11 months of our study) for 2013-2014 (χ_1^2 = 0.03, P = 0.862). The pooled survival rate during this period was 0.833. No statistically significant difference was found between male (0.670) and female (0.683) 23-month survival rates (χ_1^2 = 0.08, P = 0.777). The pooled 23-month survival rate for the study was 0.674 (Table 7).

Randel Wildlife Consulting, Inc. did not detect a statistically significant difference between male and female survival rates during pair formation in either 2012-2013 (χ_1^2 = 0.08, P = 0.777) or 2013-2014 (χ_1^2 = 0.02, P = 0.888). Researchers additionally did not find a statistically significant difference between male and female survival rates during pup-rearing in either 2013 (χ_1^2 = 1.00, P = 0.317) or 2014 (χ_1^2 = 0.78, P = 0.377). No statistically significant difference was found in male survival rates between years during either pair formation (χ_1^2 = 0.00, P = 0.964) or pup-rearing (χ_1^2 = 0.76, P = 0.383). Randel Wildlife Consulting, Inc. similarly found no difference in female survival rates between years during either pair formation (χ_1^2 = 0.10, P = 0.752) or pup-rearing (χ_1^2 = 1.00, P = 0.317) (Table 7).

Table 7: Desert Kit Fox Seasonal and Annual Survival Rates

	2012-2013		2013-2014	
	M	**F**	**M**	**F**
Pair Formation	0.868	0.885	0.891	0.836
Pup-rearing	0.944	1.000	1.000	0.923
Dispersal	1.000	1.000	1.000*	1.000*
Annual	**0.752**	**0.885**	**0.892***	**0.772***

* Partial estimate

3.2.3 Mortality Determination

Researchers identified the mortality source for 80% (12 of 15) of all mortalities during this study. Predation was the primary mortality source with 92% (11 of 12) of known fate mortalities. Seven of 11 (64%) predations were coyote with 36% (4 of 11) of predations identified as bobcat. Road kill accounted for 8% (1 of 12) of known fate mortalities.

Eleven of 15 (73.3%) of all mortalities occurred during pair formation (Nov-Feb) during our study, with 75% (9 of 12) known fate mortalities occurring during the same period. Five of seven (71%) coyote predations and 75% (3 of 4) bobcat predations occurred during pair formation. Three of 15 (20%) of all mortalities occurred during pup-rearing (Mar-Jul), with 17% (2 of 12) of known fate mortalities occurring during this period. Two of seven (29%) coyote predations occurred during pup-rearing.

3.3 Discussion

Half the female desert kit foxes successfully reproduced during our study. Our results are within previous reproductive success estimated from California (Cypher et al. 2009, Warrick et al. 1999). The study's mean litter size was 2.69 ± 0.30 and smaller than mean litter sizes in other portions of California (Cypher et al. 2009) and Utah (Egoscue 1962). Reproductive rate ranged from 1.32 in 2014 to 1.38 in 2013; mean reproductive rate was 1.35 for the entire study. Reproductive rates during our study were lower than those reported for Utah (Arjo et al. 2007, Egoscue 1962, Egoscue 1972, O'Neal et al. 1987) and California (Cypher and Scrivner 1992, Ralls and White 1995, White and Ralls 1993), with the exception of Camp Roberts, California (Standley et al. 1992). Differences in reproductive rate during our study and those previously reported are likely a combination of reduced reproductive success and mean litter size, which may be an indication of reduced prey availability in the Upper Chuckwalla Valley compared to other study areas within and outside of California.

Desert kit fox annual survival rate during this study was 0.876 for 2012-2013, with a higher female survival rate (0.885) than male survival rate (0.752). The 10-month desert kit fox survival rate was 0.833 in 2013-2014, with higher male survival (0.892) than female survival (0.772). The 23-month survival rate for desert kit foxes was 0.674 with similar male (0.671) and female (0.683) study survival rates. The study's annual survival estimate of 0.809 was similar to survival rates in Utah (0.711–1.00; Arjo et al. 2007) and Lokern Natural Area (0.84; Nelson et al.

2007); while higher than survival rates in Kern County (0.75; Disney and Spiegel 1992), Carrizo Plain National Monument (0.60; White and Ralls 1993), Utah (0.56; O'Neal et al. 1987), Camp Roberts (0.53; Standley et al. 1992), and the Naval Petroleum Reserve in California (0.35-0.46; Cypher and Scrivner 1992).

Predation was the primary mortality source (92%) during this study, which is similar to results in California (Cypher et al. 2000, Ralls and White 1995, Ralls and White 1996), Nevada (O'Neal et al. 1987), and Utah (Arjo et al. 2007). Coyote predation during this study accounted for 47% of all mortalities and 58% of all known fate mortalities. Bobcat predation was the second most common mortality source, accounting for 27% of all mortalities and 33% of all known fate mortalities. These results are consistent with findings on the Carrizo Plain Natural Area, where predation was the primary mortality source (78%) and coyote predation attributed to 88% of known fate mortalities (Ralls and White 1995). Predation of kit foxes by coyotes has been identified as the strongest known example of interspecific killing among carnivores (Palomares and Caro 1999).

Vehicular strikes were not a significant source of mortality with a single adult female being struck and killed on State Route 177 during our study. Previous research on the San Joaquin kit fox outside of urban areas found vehicular strikes were not a significant source of kit fox mortalities and unlikely to affect population dynamics (Cypher et al. 2000). Infectious diseases were also not identified as a significant source of kit fox mortality during our study; with no disease related mortalities (see Chapter 4 for discussion of infectious diseases).

No known fate or unknown fate mortalities of desert kit foxes were observed within the boundaries of the utility-scale solar facility. As discussed in Chapter 2, desert kit foxes were regularly located during nightly tracking within the solar site. Two females, one in 2012 and one in 2014 whelped litters within the solar facility. The 2012 litter was in a vegetated portion outside of an active construction zone in the northeastern portion of the site, with three pups emerging (T. Carpenter, personal communication). Six pups were whelped in 2014 in a culvert under the southwestern fence line.

CHAPTER 4:
Disease Survey

Disease surveys of the kit fox are geographically limited and primarily focused on the state and federally endangered San Joaquin kit fox (Cypher and Frost 1999, McCue and O'Farrell 1988, Standley and McCue 1997). As part of this study, disease samples were collected from 62 individual kit foxes to examine patterns of disease exposure and prevalence to address the following questions: 1) What infectious canine disease are present in the Upper Chuckwalla Valley desert kit fox population? 2) How do disease prevalence rates compare to previous research? 3) Are infectious diseases a significant source of desert kit fox mortality?

4.1 Methods

Blood samples (< 3 ml) were collected via venipuncture with 1 ml placed in an Ethylenediaminetetraacetic acid (EDTA) tube and the remaining sample placed in a serum separation tube (SST). The SSTs were centrifuged with the obtained plasma placed in sterile vials. Both whole blood and plasma were frozen pending analysis. Researchers additionally collected ocular, nasal, deep pharyngeal, and fecal swabs for analysis (Figure 6).

Figure 6: Desert Kit Fox Fecal Sampling.

Pictured: Dr. Deanna Clifford and Ms. Jaime Rudd, California Department of Fish and Wildlife.
Photo Credit: Randel Wildlife Consulting, Inc.

Samples were submitted to Integral Ecology Research Center (IERC; Blue Lake, California) for serological, real-time polymerase chain reaction (RT-PCR), and nested PCR testing. Immunofluoresence serological assays (IFA; Twark and Dodds 2000) were conducted to test for

the presence of immunoglobulin M (IgM) and immunoglobulin G (IgG) antibodies of canine distemper virus (CDV; positive titer ≥1:8), canine parvovirus (CPV; positive titer ≥1:8), canine herpes virus (CHV; positive titer ≥1:8), canine adenovirus type 2 (CAV-2; positive titer ≥1:8), and *Toxoplasma gondii* (TOXO; positive titer ≥1:64). PCR assays were conducted on DNA extracted from frozen fecal swab samples using QIAamp, DNA Stool Mini Kit (Qiagen, Valencia, California, USA) to test for CPV type 2 variants (Gabriel et al. 2010). RT-PCR were conducted on DNA extracted from ocular, nasal, and deep pharyngeal samples to test for active shedding of CDV, CHV, CAV-2, influenza virus (H3N8), parainfluenza, canine respiratory coronavirus, *Bordetella bronchiseptica*, and *Streptococcus equi* sbsp. *zooepidemicus*.

4.2 Results

On the IFA test, 3% (1 of 31) were seropositive for CPV (1:64), 3% (1 of 31) were seropositive for CDV IgM, 16% (5 of 31) were seropositive for CDV IgG, and 6% (2 of 31) were seropositive for TOXO in 2012-2013 (Table 8). One female desert kit fox had a co-infection of CDV and TOXO in the 2012-2013 sampling period. No seropositive tests occurred during the 2013 sampling (Table 8). All PCR tests were negative for CPV during the 2012-2013 sampling period, 11% (3 of 27) of PCR CPV tests were positive during the 2013 sampling. An example of a gel electrophoresis showing positive CPV amplicons from fecal samples (lanes 1, 3, and 5) with positive (lane 7) and negative (lane 6) controls, and molecular-weight size markers (lanes 2, 4, and 8) is shown in Figure 7. DNA from fecal samples, molecular-weight size makers ("ladders"), negative control (e.g. inert solution or buffer), and positive control (CPV positive sample) were placed in "wells" within the agarose gel media. An electrical current was passed through the agarose gel DNA, ladders, and control through the media to create "lanes". Samples moving through the media separate by DNA size and are compared against the ladders and controls to determine if samples were positive for CPV. For RT-PCR tests, 9% (3 of 35) were positive for *S. equi* (2 males and 1 female) in 2012-2013, whereas all other tests were negative (Table 9). All RT-PCR tests were negative in the 2013 sampling period (Table 9). Fourteen of 52 (27%) desert kit foxes sampled during our study tested positive for the presence of an infectious disease. CDV (IgG and IgM) was the most prevalent (12%) disease documented, followed by CPV (10%), *S. equi* (6%), and TOXO (4%).

Table 8: Number of Seropositive Desert Kit Foxes Tested for Infectious Disease Antibodies, Upper Chuckwalla Valley, Riverside County, California (2012-2013).

Sampling Period	Age	Sex	*n*	CPV (IgG)	CDV (IgG)	CDV (IgM)	CHV (IgG)	CAV-2 (IgG)	TOXO (IgG)
2012	A	M	11	0	2	0	0	0	0
	A	F	12	1	3	1	0	0	1
	J	M	4	0	0	0	0	0	0
	J	F	4	0	0	0	0	0	1
2012 Total			**31**	**1**	**5**	**1**	**0**	**0**	**2**
2013	A	M	5	0	0	0	0	0	0
	A	F	7	0	0	0	0	0	0
	J	M	5	0	0	0	0	0	0
	J	F	3	0	0	0	0	0	0
2013 Total			**20**	**0**	**0**	**0**	**0**	**0**	**0**
Total			**51**	**1**	**5**	**1**	**0**	**0**	**5**

Table 9: Number Real-Time PCR Positives for Desert Kit Foxes Tested for Infectious Diseases, Upper Chuckwalla Valley, Riverside County, California (2012-2013).

Sampling Period	Age	Sex	*n*	CDV	CHV	CAV-2	H3N8	PI	*B.bron*	*S.equi*
2012	A	M	13	0	0	0	0	0	0	1
	A	F	12	0	0	0	0	0	0	1
	J	M	5	0	0	0	0	0	0	1
	J	F	5	0	0	0	0	0	0	0
2012 Total			**35**	**0**	**0**	**0**	**0**	**0**	**0**	**3**
2013	A	M	7	0	0	0	0	0	0	0
	A	F	9	0	0	0	0	0	0	0
	J	M	6	0	0	0	0	0	0	0
	J	F	5	0	0	0	0	0	0	0
2013 Total			**27**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total			**62**	**0**	**0**	**0**	**0**	**0**	**0**	**3**

Figure 7: Gel Electrophoresis of Positive Amplicons of Canine Parvovirus (Lanes 1, 3, 5), Positive Control (Lane 7), Negative Control (Lane 6), and Ladders (Lanes 2, 4, 8) from Fecal Swabs.

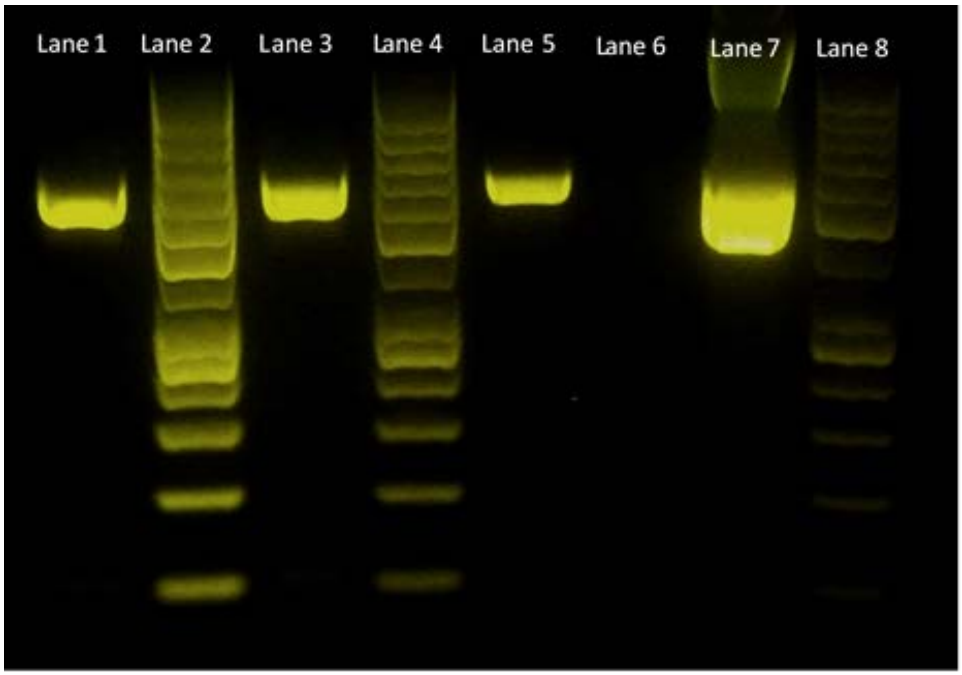


Photo Credit: Integral Ecology Research Center.

4.3 Discussion

Infectious canine diseases were present in the Upper Chuckwalla Valley desert kit fox population during our study, with 27% of tested individuals showing previous exposure to at least one disease antibody. As discussed in Chapter 3 of this report, no disease related mortalities were identified during this study.

Canine distemper virus prevalence was highest during the 2012 sampling period with 19% (6 of 31) individuals tested positive for previous exposure. All CDV seropositive individuals were adults, with female prevalence (33%; 4 of 12) higher than male prevalence (18%; 2 of 11). Canine distemper virus antibodies were not detected during the 2013 sampling period. No evidence of active CDV shedding was found during the study. CDV prevalence in this study area was similar to those reported at Camp Roberts (20%; Standley and McCue 1997). Conversely, CDV prevalence rates in the Upper Chuckwalla Valley were higher than those reported in kit fox populations at Elk Hills (10%; McCue and O'Farrell 1988), urban Bakersfield (0%; Cypher and Frost 1999), and the Naval Petroleum Reserves in California (6%; Cypher and Frost 1999). Similarly, our CDV prevalence rates were higher than a range wide canine infectious disease survey conducted by Miller et al. (2000), who reported a 5% CDV prevalence rate.

During the 2012 sampling 3% (1 of 31) individuals, an adult female, were seropositive for previous exposure to CPV. Canine parvovirus prevalence was highest during the 2013 sampling period with 11% (3 of 27) individuals actively shedding CPV. Prevalence rates of CPV in the Upper Chuckwalla Valley were lower than previously reported in kit fox populations at the Elk

Hills (23–81%; McCue and O'Farrell 1988), Camp Roberts (32-72%; Standley and McCue 1997), urban Bakersfield (83%; Cypher and Frost 1999), and the Naval Petroleum Reserves in California (98%; Cypher and Frost 1999). The CPV prevalence rate was similar to, but lower, than the range wide prevalence rate of 14% (Miller et al. 2000).

Desert kit foxes in the Upper Chuckwalla Valley showed previous exposure to *Toxoplasma gondii* during the 2012 sampling with a prevalence of 6% (2 of 31). Both TOXO positive individuals were females, one adult and one juvenile. TOXO was not detected during the 2013 sampling. Prevalence rates of TOXO during our study were lower than the Elkhorn Plain (20%; McCue and O'Farrell 1988) and Camp Roberts (18%; Standley and McCue 1997).

Similar to our TOXO results, desert kit foxes in the Upper Chuckwalla Valley showed previous exposure to *Streptococcus equi* ssp. *zooepidemicus* with a prevalence of 9% (3 of 35), and no individuals testing positive in the 2013 sampling period. Previous prevalence rates for *Streptococcus equi* ssp. *zooepidemicus* in kit foxes were not found for comparison.

In the absence of pre-construction baseline disease prevalence rates for the Upper Chuckwalla Valley desert kit fox population researchers cannot definitively state whether increased anthropogenic activity associated with utility-scale solar energy development had an effect on disease prevalence. Multiple studies suggest that many epizootics exhibit cyclic patterns (Follmann et al. 1992, Ballard et al. 2001) and may have a strong seasonal component (Cartron et al. 2000, Cooper et al. 2004). Long-term research efforts would be required to identify if desert kit fox disease prevalence exhibit cyclic patterns and/or seasonal outbreak patterns.

CHAPTER 5:
Genetics

Genetic studies of the kit fox have primarily focused on the state and federally endangered San Joaquin kit fox (Schwartz et al. 2005, Smith et al. 2006). As part of this overall study of desert kit foxes in the Upper Chuckwalla Valley, genetic analyses were performed on 95 individual foxes. Both nuclear and mitochondrial markers were used to examine patterns of variation among marked individuals in an effort to address the following questions: 1) What is the level of genetic relatedness among marked individuals? 2) Is there one or more genetically-defined populations in the area being surveyed? 3) Do males and females differ from each other as a result of male biased dispersal? 4) How do overall levels of genetic variation compare to foxes from other regions?

5.1 Methods

5.1.1 Tissue Collection and DNA Extraction

A 2 mm ear tissue sample was taken via punch biopsy during capture, handling and marking, and DNA was extracted from each sample. Punch biopsies are one of the least invasive tissue sampling methods (Seltzer 2007) and are known to both heal quickly and be less subject to infection (Iaizzo et al. 2012). The collected tissue sample was placed in a labeled (e.g., PIT and ear tag identification) vial containing 100% ethanol (ETOH) and stored in a -20°C freezer for later analysis.

DNA was isolated from 95 kit fox. Ear plugs were diced with a razor blade in preparation and macerated further with a 1.5 mL disposable dounce. A Qiagen DNeasy Blood and Tissue Kit (Qiagen, Valencia, CA) was then used to further isolate whole genomic DNA. This procedure involved the following: 1) placement of diced tissue in a solution containing 100 µL ATL buffer and 20 µL of proteinase K. The mixture was vortexed and placed on a shaking incubator set at 56°C. It was then incubated for 24 hours or more, as ear tissue requires more time to totally digest the materials and lyse the cells. After incubation, 200 µL of AL buffer was added to the sample, and the tube was vortexed. Immediately following this step, 200 µL of 100% ethanol was added, and the sample was vortexed again. This solution was added to a QIAmp Mini spin column and centrifuged for 8000 rpm for 1 minute. The flow through was discarded, and 500 µL of Buffer AW1 was added to the spin column. The column was spun again at 8000 rpm for 1 minute, the flow through was discarded, and 500 µL of AW2 was added to the spin column. The column was centrifuged for 14,000 rpm for 3 minutes, and 200 µL of AE buffer was added to a new tube. The tube was centrifuged at 8,000 rpm for 1 minute. The final solution contained the DNA.

The amount of DNA was determined on a Nanodrop spectrophotometer. The average concentration was approximately 10 nanograms (ng) per microliter (µL).

5.1.2 Microsatellite Genotyping

Twelve primer pairs were selected for PCR amplification of microsatellite loci (Table 10). Primer pairs were obtained from the following sources: 1) CPH3, CPH5, CPH7 (Fredholm and Wintero 1995); 2) FH2054, FH2137, FH2140, PEZ19 (Francisco et al. 1996); 3) FH2226 (Mellersh et al. 1997); and 4) CXX20, CXX172, CXX173 (Ostrander et al. 1993). The forward primer of each pair was labeled with a florescent (6-Fam and Hex, denoted Glo6 and Glo8, respectively, in Table10).

PCR amplification was performed in 25 μL containing 0.25 μL of TaKaRa *Taq*™ polymerase, 2.5 μL of 10X buffer, 1 μL of each primer, 1-2 μL template DNA, 2 μL $MgCl_2$, and 0.25 μL of dNTPs. Depending on the amount of template used, sterile, deionized water was added to bring the total volume to 25 μL. PCR conditions were as follows: Initial denaturation (1 cycle) – 95°C, 5 min; (35 cycles) – denaturation at 95°C, 1 min, annealing for 1 min at temperature appropriate for primer set (Table 10), extension at 72°C for 2 min; (1 cycle) 72°C for 4 minutes.

Prior to genotyping, PCR fragments were produced using the protocol listed above, and the intensity and presence of amplification product was verified by electrophoresis of 12.5 μL of amplification product across a 1.5% agarose gel containing ethidium bromide. A BioRad gel imaging system was used to quantify the amount of amplification product relative to a 1 Kb ladder as the standard. Each amplification product was diluted with water based on the intensity of the amplification product. HiDi formamide was added to 1 μL of amplification product prior to loading on an optical plate. Fragment analysis was performed on an ABI (Applied Biosystems) 3130 automated sequencer, and allele sizes were determined using GeneMapper (ABI) and a ROX400 size standard.

5.1.3 Nucleotide Sequencing

All of these microsatellite loci were initially characterized for the domestic dog, *Canis familiaris*. Therefore, researchers sequenced several homozygous individuals for each of the loci to confirm the repeat motif of each locus for the kit fox. PCR for sequences was performed in 25 μL reaction volumes containing: 2 μL 25 mM $MgCl_2$, 2.5 μL buffer, 2 μL dNTPs, 0.25 μL TaKaRa *Taq*™, 1 μL of each primer, and 15.25 μL dH_2O. Reaction conditions included an initial denaturation at 95°C for 5 min (1 cycle) followed by 35 cycles consisting of 93°C (1 min), 55°C (1 min), 72°C (2 min), and a final extension at 72°C for 4 min.

A Pre-sequencing Kit from USB (Swampscott, MA) was used to remove excess primers by treating 5 μL of PCR product with 1 μL of Exonuclease I (10 units/ μL) and 1 μL of Shrimp Alkaline Phosphatase (2 units/ μL) at 37°C for 15 min. Sequencing was performed with Big Dye Terminator v1.1 following the recommendations of the supplier (Applied Biosystems, Foster City, CA). Prior to sequencing, excess dye terminators were removed with a Dye Ex 2.0 Spin Kit following the recommendations of the supplier (Qiagen, Valencia, CA). Both strands of each template were sequenced on an ABI 3130 automated sequencer, and consensus sequences were constructed with the program Sequencher 4.7 (Gene Codes, Ann Arbor, MI).

Table 10. Primer Pairs (F = forward, R = reverse) Used for Amplification of Microsatellite Loci.

Primers[1]	Sequences	Length	Repeat Type	PCR Product Size	Chromo[2]	Temp[3]
1 CPH3aFGlo8	8CAGGTTCAAATGATGTTTTCAG	22bp	$(GA)_2TA(GA)_{17}$	154-182 bp		50°C
CPH3bR	TTGACTGAAGGAGATGTGGTAA	22bp				
2 CPH5aFGlo8	8TCCATAACAAGACCCCAAAC	20bp	$(TG)_{17}$	111-141 bp	17	50°C
CPH5bR	GGAGGTAGGGGTCAAAAGTT	20bp				
3 CPH7aFGlo6	6ACACAACTTTCCATAATACTTCCCA	25bp	$(TG)_{16}$	159-173 bp		50°C
CPH7bR	ATCAATGCTCTCCTCCCCAG	20bp				
4 FH2137HFGlo6	6GCAGTCCCTTATTCCAACATG	21bp	$(GAAA)_{21}$	185 bp	3	50°C
FH2137LR	CCCCAAGTTTTGCATCTGTT	20bp				
5 PEZ19HFGlo8	8 GACTCATGATGTTGTGTATC	20bp	$(TAAA)_{10}$	195-211 bp	20	50°C
PEZ19LR	TTTGCTCAGTGCTAAGTCTC	20bp				
6 CXX20FGlo6	6AGCAACCCCTCCCATTTACT	20bp	$(CA)_{21}$	112–135 bp	11	52°C
CXX20R	TTGATCTGAATAGTCCTCTGCG	22bp				
7 CXX172FGlo8	8CCTGTCTCCTGTGGACCAAT	20bp	$(TG)_{12}$	156–164 bp		58°C
CXX172R	ACATGCAAAAGGACACATTACG	22bp				
8 CXX173FGlo6	6ATCCAGGTCTGGAATACCCC	20bp	$(TG)_{17}$	124–128 bp	9	55°C
CXX173R	TCCTTTGAATTAGCACTTGGC	21bp				
9 FH2054FGlo8	8GCCTTATTCATTGCAGTTAGGG	22bp	$(GATA)_{16}$	167–191 bp	12	55°C
FH2054R	ATGCTGAGTTTTGAACTTTCCC	22bp				
10 FH2140FGlo6	6GGGGAAGCCATTTTTAAAGC	20bp	$(GAAA)_{18}$	146 bp	5	58°C
FH2140R	TGACCCTCTGGCATCTAGGA	20bp				
11 FH2226FGlo6	GGACTACCCCATTGCATTTG	20bp	$(GAAA)_6$	128-174 bp	7	65.7°C
FH2226R	GAATCGAGTCCCATATCGGG	20bp				

Researchers sequenced a 1126 bp fragment of the mitochondrial DNA (mtDNA) cytochrome b gene for 95 individuals. The same protocol mentioned above was used. Sequences were aligned in Sequencer 4.7, and contigs were constructed from sequences obtained from both strands.

5.1.4 Data Analysis

All genotypic data from the microsatellite markers were collated by population in an Excel spreadsheet. *GenAlEx* 6.41 (Peakall and Smouse 2006) was used to estimate several population statistics including observed versus expected heterozygosity, number of alleles per locus, number of private alleles per population, allele frequency per population, and the level of geographic subdivision in the samples examined. In addition, the same program was used to test for deviation from Hardy-Weinberg expectations to assess if the study population is randomly mating, which may be very important in potentially inbreeding populations. Patterns of genetic divergence and gene flow among populations were examined using several methods. First, an Analysis of Molecular Variance (AMOVA) was employed in *GenAlEx* 6.41 to test for statistically significant subdivision among populations. Second, F_{ST} (the fixation index) among populations was estimated from allele frequencies, and *Nm* (number of migrants per generation) was derived from F_{ST}. Third, a Bayesian approach in the program STRUCTURE version 2.3 (Pritchard et al. 2000) was used to estimate the number of populations (k) without use of prior assumptions (e.g., predefined populations). This particular approach allows for the assignment of individuals to populations based on their genotypes, and it provides a means of assessing the degree of admixture (e.g., gene flow) between populations.

In addition to the above population genetic analyses, models related to both isolation by distance and spatial autocorrelation were evaluated using a combination of genotypic data and known GPS coordinates. Several programs, including *GenAlEx*, Arlequin (Excoffier et al. 2005), and GENEPOP (Raymond and Rousset 1995), were used to perform these analyses.

All mtDNA sequences were used to create a Nexus file in PAUP* version 3.2 (Swofford 2002). Estimates of relationships among unique mitochondrial haplotypes were determined in PAUP. Both ARLEQUIN v. 3.0 (Excoffier et al. 2005) and DNASP v. 5.10.1 (Rozas et al. 2003) were used to estimate haplotype diversity, nucleotide diversity, and the mean number of differences among haplotypes. These data were also used to estimate population differentiation and the female effective population size.

5.2 Results

5.2.1 Microsatellite Variation

Nine of the 12 loci were in Hardy-Weinberg equilibrium, and overall the population was in equilibrium (Table 11). The number of alleles per locus averaged 9.3 (range 5 to 19), and expected and observed heterozygosity averaged 0.677 and 0.685, respectively. Thus there was little evidence of inbreeding, with both F_{IS} (inbreeding coefficient) and relatedness among all pairs being effectively zero.

The data were also partitioned into two groups (females, Pop1 and males, Pop2) in an effort to see if females showed a higher overall genetic similarity than males. Basically, researchers were testing the hypothesis that males are more likely to disperse, whereas females would show

fidelity to their birth site. Therefore, one should see less genetic similar among males than seen for females. This hypothesis was tested in several ways. First, an assignment test was performed, whereby each individual was assigned to either the female or the male group. As can be seen in the Table 12, only half of the individuals from a particular group were actually assigned to the correct group.

Second, a principle coordinates analysis was performed, which grouped individuals by genotype. Again, there was no apparent separation of females and males, Pop 1 and Pop 2, respectively (Figure 8).

Although not shown, a STRUCTURE analysis of the microsatellite data indicated that there was only one population, with no evidence of population subdivision.

Table 11: Variation Across 12 Microsatellite Loci

Locus	Number of Alleles	Observed Heterozygosity	Expected Heterozygosity	Hardy-Weinberg Equilibrium[1]
CPH3	5.0	0.453	0.488	***
CPH5	10.0	0.766	0.759	ns
CPH7	5.0	0.232	0.223	ns
CXX20	10.0	0.821	0.796	ns
CXX172	7.0	0.495	0.512	ns
CXX173	4.0	0.462	0.432	**
FH2054	9.0	0.777	0.815	ns
FH2137	13.0	0.874	0.859	ns
FH2140	12.0	0.926	0.866	ns
Pez19	6.0	0.747	0.757	ns
FH2226	11.0	0.758	0.693	**
FH2561	19.0	0.905	0.922	ns
Average	9.3	0.685	0.677	

[1]ns = nonsignifcant, *** = P<0.001, ** = P<0.01

Table 12: Summary of Population Assignment to Self or Other Population

Pop	Self Pop	Other Pop
Pop1	18	17
Pop2	20	25
Total	38	42
Percent	48%	53%

5.2.2 Mitochondrial Variation

Researchers sequenced 1126bp of the mitochondrial cytochrome b gene for 95 individuals. They found 10 mitochondrial haplotypes, a unique and maternally inherited mitochondrial sequence. Mitochondrial haplotype diversity is high with 10 haplotypes observed. Haplotypes 1, 2, and 3 (35%, 26%, and 14%, respectively) are in the highest frequency, with seven haplotypes in relatively low frequency. Overall haplotype diversity was 0.80, and the average number of nucleotide differences per haplotype was 1.6. Males and females showed no fixed differences and had similar levels of haplotype diversity (females = 0.71 and males = 0.84). There was no apparent relationship among haplotypes that correlated with either gender or geographic locality (Figure 9). Figure 9 depicts relationships among various unique mitochondrial haplotypes. Researchers found limited evidence based on haplotype frequencies for male and female kit foxes to suggest sex-specific dispersal patterns at the study site.

Figure 8: Principal Coordinates Analysis (PCoA) Based on Genotypic Data.

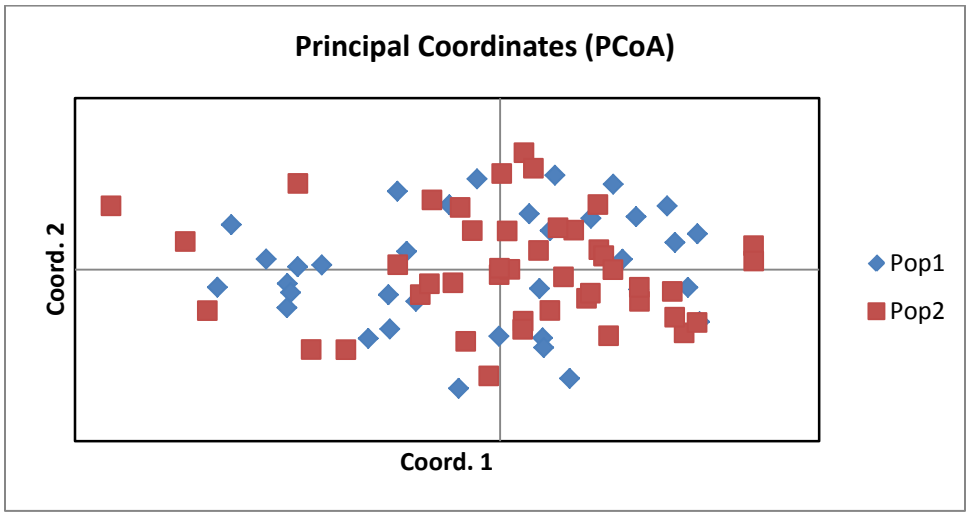
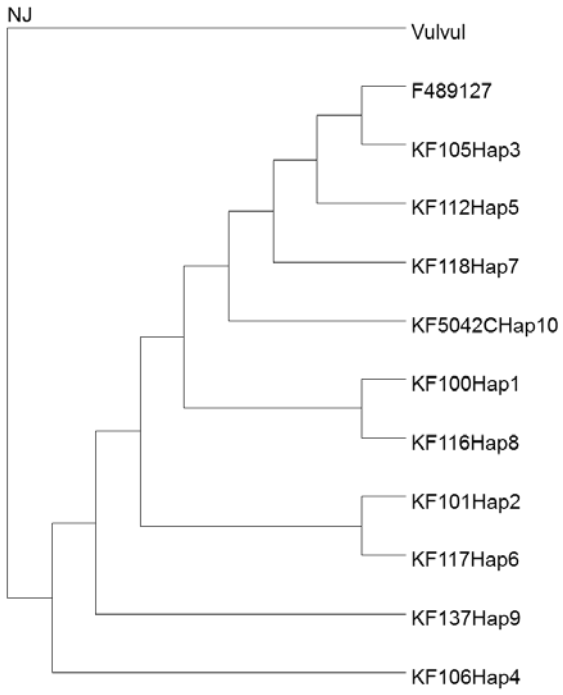


Figure 9: Neighbor-Joining Tree Derived from a Parsimony Analysis of the Ten Haplotypes, with *Vulpes vulpes* used as an Outgroup.



5.3 Discussion

Based on genetic data from both mitochondrial DNA sequences and microsatellite loci, the kit fox in this region appears to have a high level of variation. In comparison to other species of *Vulpes* (Table 13), *Vulpes macrotis* in this region of the Colorado Desert has a higher number of alleles per locus and expected heterozygosity, with only *Vulpes velox* approaching similar levels of variation. In addition, this particular population appears to be panmictic, or randomly mating population, with no evidence of genetic subdivision or distinct differences between males and females. Although the overall level of genetic relatedness was low (Table 13) among all individuals, there were some pairs, primarily offspring and parents, that showed considerably higher levels of relatedness.

In conclusion, the kit foxes in this region appear to be a genetically diverse population with no evidence of inbreeding or population subdivision.

Table 13: Comparison to Other Species of *Vulpes*

Species	Alleles Per Locus	Expected Heterozygosity	Mean Relatedness	Source
Vulpes macrotis arsipus	6.0	0.677	-0.011	This Study
Vulpes macrotis mutica	3.8	0.50	-0.07	Ralls et al. (2001)
Vulpes macrotis mutica	4.63	0.39		Schwartz et al. (2005)
Vulpes velox	6.09	0.61	0.008	Kitchen et al. (2005)

CHAPTER 6:
Summary

The results of this two-year investigation on the life history and ecology of desert kit foxes in the Upper Chuckwalla Valley, Riverside County, California represent baseline data for the species in the region. These data are the first for the region and may be used during environmental assessments where impacts to desert kit foxes could be anticipated. Based on the genetic analyses, the Upper Chuckwalla Valley has a single desert kit fox population. This population exhibited high genetic variation for both mitochondrial DNA (10 haplotypes) and microsatellite loci. Genetic diversity within our study population had a higher number of alleles per loci and expected heterozygosity than previous kit fox studies (Ralls et al. 2001, Schwartz et al. 2005). While inbreeding was not detected during our study, we did find a high degree of relatedness within certain familial groups, which may be an indication of lower emigration rates than expected (Gompper et al. 1998).

Familial groups consisted primarily of mated pairs, who maintained relatively stable, independent home range configurations throughout our study. Mated pairs during our study also exhibited a high percent overlap (77.6 ± 1.8%) between pair-bonded individuals and lower overlap (20.9 ± 1.0%) between unpaired adjacent individuals, which is consistent with previous findings (Daneke et al. 1984, Zoellick and Smith 1992). Our mean annual fixed kernel home range size was 3,897 ± 376 acres and did not differ significantly between males and females. Annual home range sizes during our study were significantly larger than previous kit fox estimates for Arizona (Zoellick and Smith 1992), Utah (Daneke et al. 1984, O'Neal et al. 1987), Mexico (List and Macdonald 2003), and California (Cypher et al. 2001, Nelson et al. 2007, White and Ralls 1993). Low sample size (List and Macdonald 2003, Zoellick and Smith 1992), infrequent study animal location (List and Macdonald 2003, Zoellick and Smith 1992), and differences in habitat characteristics (Cypher et al. 2001, Daneke et al. 1984, List and Macdonald 2003, O'Neal et al. 1987, White and Ralls 1993) may explain, in part, why home range sizes were smaller in other studies than in the Upper Chuckwalla Valley during this study. While data on prey availability was not collected during this study, variation in home range size between years at the same study location have been attributed to variation in prey resources (Haight et al. 2004, White and Garrott 1997, White and Ralls 1993). Extrapolating from mean annual home range size and percentage overlap, mated kit fox pairs used an area of approximately 4,769.93 acres in a calendar year.

Prey availability has also been linked to reproductive success in kit foxes (Haight et al. 2004). During our study 50% of radio collared female desert kit foxes successfully whelped ≥1 pup in 2013 and 2014. While reproductive success during our study was similar to previous findings (Cypher et al. 2009, Warrick et al. 1999), the study's reproductive rate (1.35) was significantly lower than all locations, with the exception of Camp Roberts, California (Standley et al. 1992). Breeding season drought condictions during this study range from severe to extreme in 2013 and extreme for the entire 2014 breeding season (National Climate Date Center 2014). Drought conditions during this study may have influenced reproductive parameters by reducing small

mammal prey availability (Dennis and Oten 2000) and increasing water stress (Girard 2001, Golightly and Ohmart 1983). This finding reinforces the idea that prey resources may have been a limiting factor to reproduction during our study.

In contrast to these findings that desert kit foxes in the Upper Chuckwalla Valley had lower reproductive rates when compared to other kit fox studies, annual survival rates (0.752-0.885 during this study were higher than all previous studies, excluding at the Lokern Natural Area (Nelson et al. 2007). High annual survival combined with a reproductive rate >1.0 indicate the Upper Chuckwalla Valley desert kit fox population is stable to increasing at present, and unlikely affected by the presence of an adjacent utility-scale solar energy facility.

Researchers investigated cause-specific mortality during our study and identified predation as the primary desert kit fox morality source, which is consistent with previous findings (Arjo et al. 2007, Cypher et al. 2000, O'Neal et al. 1987, Ralls and White 1995, Ralls and White 1996). All but one of the mortalities during our study were predations, with coyotes identified as the dominant kit fox predator during our study. A single desert kit fox died as a result of a vehicular strike during this study and was the only anthropogenic related mortality. Additionally, there was no disease related mortality event during our study.

Randel Wildlife Consulting, Inc. collected samples suitable for disease testing in 2012 and 2013. All of our collected disease samples were submitted to Integral Ecology Research Center to test for the presence of disease antibodies. Researchers found that 27% of all desert kit foxes tested positive for the presence of at least one disease antibody during our study. The overall results based on serological sampling identified canine distemper virus as the most prevalent disease with a 12% prevalence rate, the second most prevalent disease was *Toxoplasma gondii* with a 10% prevalence rate, followed by canine parvovirus with a 2% prevalence rate. Overall disease prevalence rates based on swab sampling found equal prevalence rates (5%) for canine parvovirus and *Streptococcus equi* sbsp. *zooepidemicus*.

Differences in home range size, reproductive rate, survival rate, and disease prevalence may be related to stochastic environmental variables unaffected by land conversion from native habitats to energy development. The 550-MW solar farm operating in the Upper Chuckwalla Valley has an approximate area of 3,700 ac, accounting for approximately 6% of our total study area. The total area of the solar farm covers an area less than the mean annual home range for desert kit foxes during our study. Land lost due to conversion has reduced foraging opportunities for desert kit foxes within and immediately adjacent to the development, but has not completely excluded use by desert kit foxes.

As with any study, there are several limitations that preclude making general conclusions about the potential impacts of solar energy development on desert kit foxes in California. First, the study was limited to a single valley in the Colorado Desert, whereas desert kit fox range covers essentially all of the DRECP plan area. It would be premature to conclude that this single site, and one population of kit fox, is representative of the whole California portion of the range. Second, the study period was limited to two years and thus highly constrained by weather and other environmental conditions during that period. It would take a longer duration study to

establish the natural range of variability in kit fox life history parameters, such as home range size, reproduction success and rates, survivorship, and disease prevalence. Third, the study occurred during the construction phase of the Desert Sunlight Solar Farm project. It remains to be seen how the desert kit foxes adapt to the presence of the facility during its operations and maintenance phase.

Nevertheless, this research is providing scientifically collected baseline data to the DRECP on the ecology and life history traits of the desert kit fox at a utility-scale solar energy development project in California. Data collected in support of this project provides reliable estimates of home range size, reproductive success/rate, survival, cause specific mortality, disease prevalence, and genetics, which can be used in the decision making process to assess potential impacts to desert kit foxes resulting from utility-scale solar energy development. With knowledge of how utility-scale solar projects affect the ecology of the desert, California can move forward with proactive siting as well as mitigation efforts to better facilitate the permitting of renewable energy projects, such as for the DRECP implementation.

GLOSSARY

Term	Definition
ATL	A tissue lysis buffer used in purification of nucleic acids
AW1	An ethanol-based stringent wash solution containing low concentration of guanidine
AW2	A Tris-based solution containing ethanol
BLM	Bureau of Land Management
CAV2	Canine Adenovirus Type 2
CDV	Canine Distemper Virus
CHV	Canine herpes virus
CPV	Canine Parvovirus
Disease Prevalence	The number of individuals testing positive for a selected disease divided by the number of individuals sampled
DNA	Deoxyribonucleic acid
DRECP	Desert Renewable Energy Conservation Plan
EDTA	Ethylenediaminetetraacetic acid
ESRI	Environmental Systems Research Institute
F_{IS}	Inbreeding coefficient
F_{ST}	Fixation index
GME	Geospatial Modelling Environment
GPS	Global Positioning System
GW	Gigawatt
GWh	Gigawatt-hour
Home Range	An area traversed by an individual in its normal activities of food gathering, mating, and caring for young.
IERC	Integral Ecology Research Center
IFA	Immunofluoresence serological assays
IgG	Immunoglobulin G

IgM	Immunoglobulin M
LOAS	Location Of A Signal
MCP	Minimum Convex Polygon
mtDNA	Mitochondrial DNA
MW	Megawatt
PCR	Polymerase Chain Reaction
PIER	Public Interest Environmental Research
PIT	Passive Integrated Transponder
PV	Photovoltaic
Reproductive Rate	Product of mean litter size and proportion of females successfully breeding
Reproductive Success	The number of known individuals successfully reproducing divided by the number of known individuals within a population of interest
RPS	Renewable Portfolio Standard
RPS	Renewable Portfolio Standard
RT-PCR	Real Time – Polymerase Chain Reaction
SST	Serum separation tube
Survival rate	The number of known individuals surviving for a predefined time period (e.g., season and annual)
TOXO	*Toxoplasma gondii*
USGS	United States Geological Survey
VHF	Very High Frequency

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